Hidden Valley Higgs Search

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Introduction

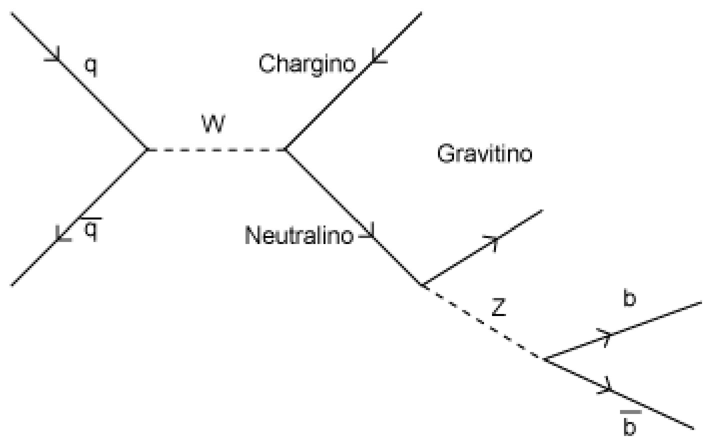
- The Problem
  - Searches Outside the SM: displaced vertices
- Phenomenology
  - Hidden Valley Model
- Signal Monte Carlo Studies
- TStnSVF – custom b-tagger
  - Quick comparison to SecVtx
- New Variables – a look for basic discriminants
  - Backgrounds
- The Analysis
  - Signal Monte Carlo
  - Setting the max d_0 cut
  - Determining background from data

Displaced vertices

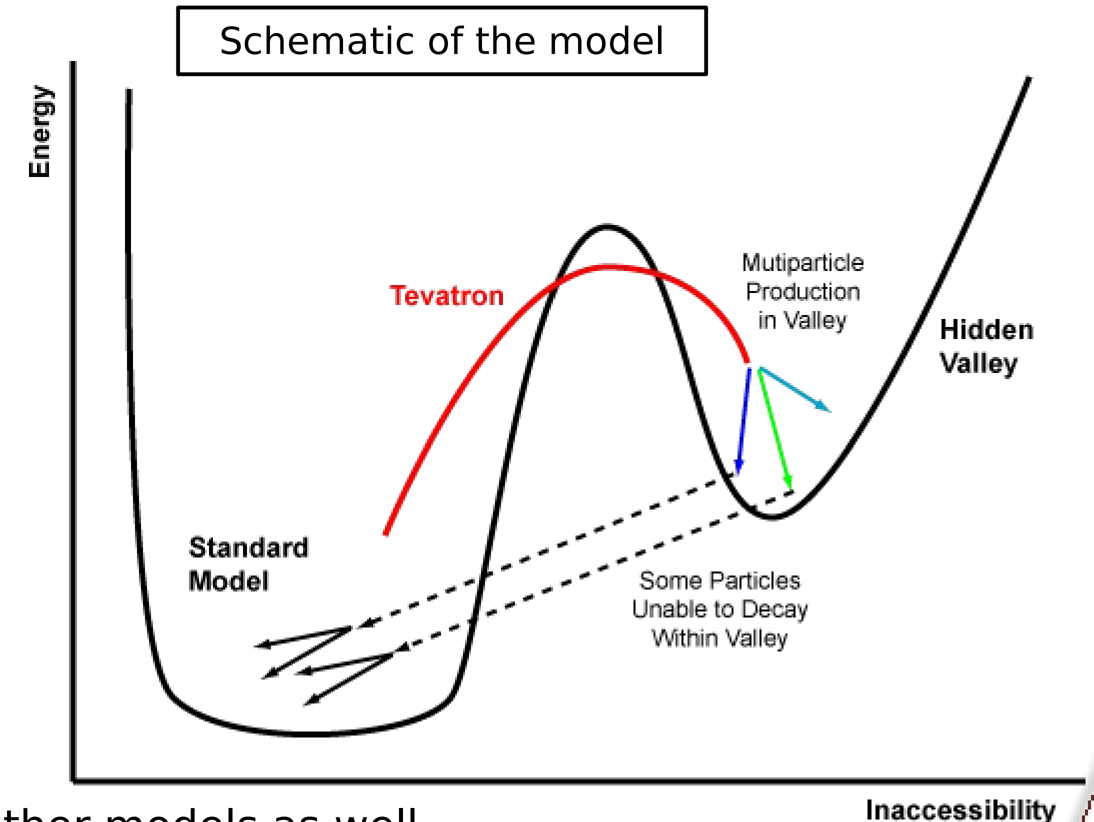
- Why look at displaced vertices?
  - It is an interesting signature outside of the SM.
  - While there are long lived particles in the SM (K, D, & B hadrons) there are few SM processes for two massive objects originating from a single common vertex.
- Some Previous Analyses:
  - Done at CDF-looking for a long-lived particle decaying into $Z \to e^+e^-$ and $Z \to \mu^+\mu^-$ by looking at the tracking information.
    - Finds the track intersection of the leptons, and looks for a large distance between this intersection and the primary vertex.
  - Done at D0-looking for a long-lived particle decaying into $Z \to e^+e^-$ by looking at calorimeter information.
    - D0 Electro-Magnetic calorimeter is finely segmented, allowing for vertex resolution.
- Because we can.
  - CDF employs a Silicon Vertex Trigger (SVT) that can trigger on displaced tracks.
  - This trigger allows us to enrich our signal while reducing the QCD background present at hadron colliders.
- What are we looking for:
  - In general we are searching for a long lived massive object decaying into two quarks, which then hadronize into jets in the detector.

Phenomenology

- There are a number of theories where displaced vertices play a role.
  - Hidden Valley model by Matt Strassler (Rutgers) and others.
    - The SM communicates with a Hidden Valley with valley (or v-) particles.
    - We wound up adopting this model for our search.
    - See next slide for more details.
  - Gauge-mediated SUSY models where the gravitino is the Lightest Stable Particle (LSP).
    - If the next to lightest stable particle (NLSP) has a large $\tilde{Z}$ content, then it may decay to a Z^0 boson and the LSP.
    - The sparticle content of the NLSP is a free parameter in some SUSY models.



Hidden Valley



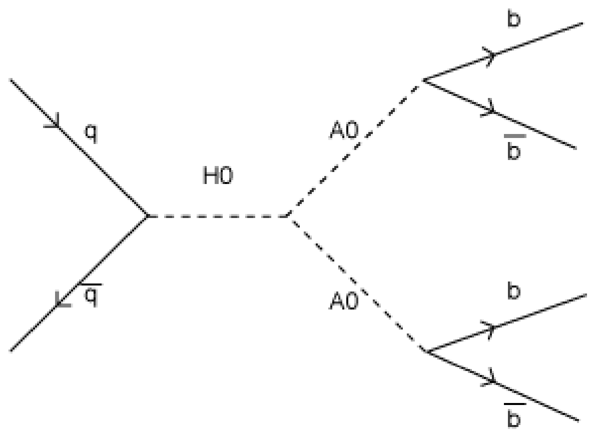
- Energy from collisions enter into the new sector.
- It is transformed into multiple particles through the dynamics of the new sector.
  - These valley-particles (or v-particles) behave in the same way as SM particles.
  - They obey a “v-QCD,”
  - Most likely decay is a v-π.
- Some of these particles decay back into SM particles.
- This model can co-exist with other models as well.
  - SUSY, technicolor, etc.
- It may help in the search for the Higgs.
  - The Higgs may decays into long-lived neutral v-particles, which are heavy and meta-stable. They would decay at a displaced vertex.
  - These would then decay into the heaviest SM fermion available (b-quarks).
- Because this sector is dark, there may be Dark Matter/Astrophysics connections as well.
- In some models (see Kaplan, Luty, Zurek) cτ for the heavy metastable particle could be of order 1 cm.

Hidden Valley

- The Hidden Valley model provides a large, and dark, sector which is weakly constrained by current experiments.
  - In general, experiments at LEP, CDF, BABAR have little or no constraints on neutral particles with small couplings to photons or Z.
  - In particular particles that have no weak, electric or color charge.
- Because this model has few constraints, there are a large number of experimental signatures that are possible.
  - We have chosen to concentrate on one signature, displaced vertices, and one model, Higgs production.
  - The signature provides sensitivity to a broad range of heavy metastable particles.
  - The model provides a benchmark result that can later be translated for other theories.
- Although we are looking for a Higgs, this search is signature based. Any particle which decays in such a fashion, with a displaced vertex into b-bbar pairs, can be the source of our signal.

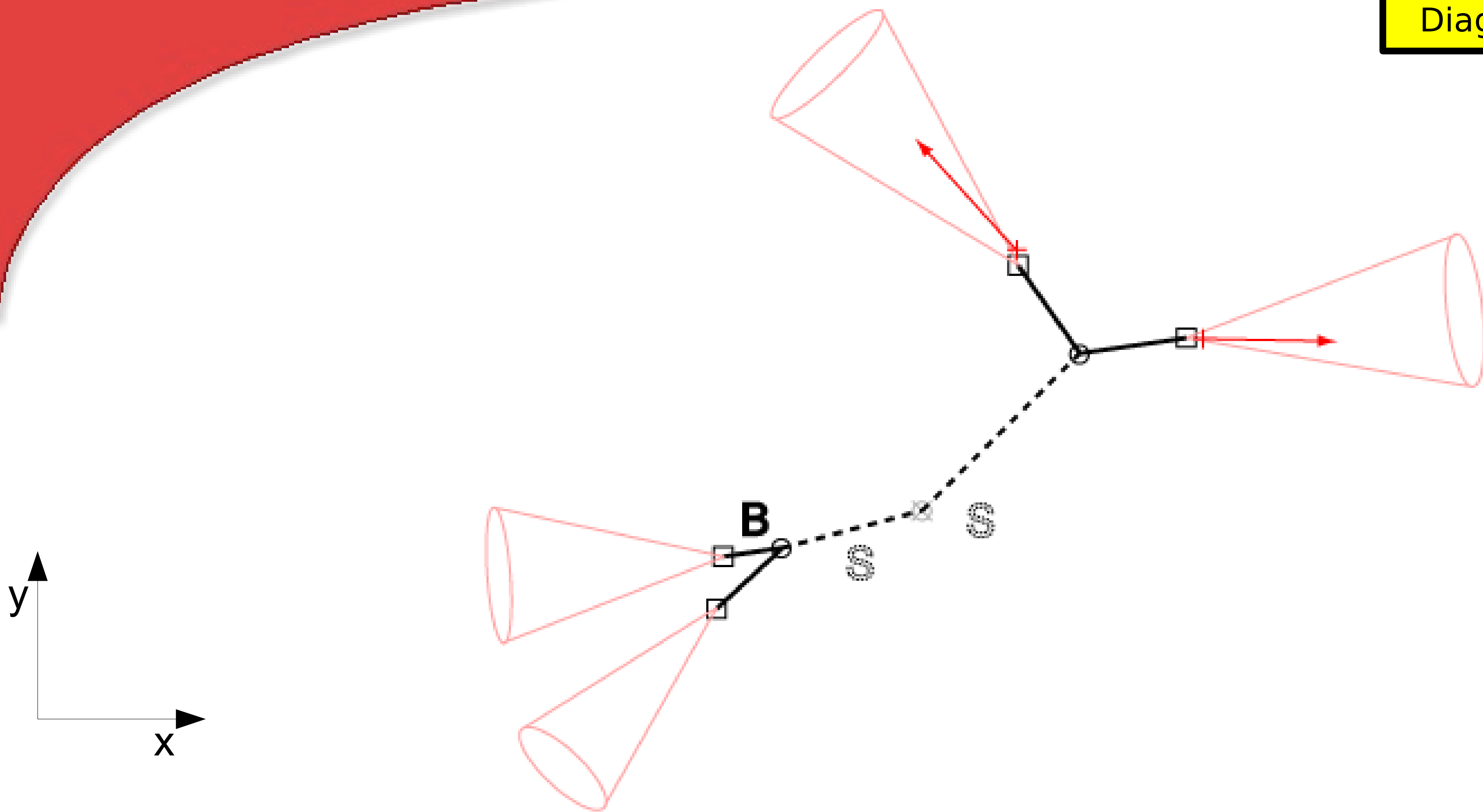
MC Studies

- First thing we did was generate some signal MC to study. This was done with Pythia w/ the CDF detector simulation and CDF "tunes."
  - The decay chain is: $H_0 \rightarrow A_0\ A_0 \rightarrow$ b,bbar, b,bbar.
  - Here the Higgs is a MSSM Higgs.
    - The Higgs has been constrained to decay into A_0s.
  - The A_0 represents a hidden valley particle (v-π) that has a long lifetime.
    - The proper lifetime studied so far is $c\tau = 1.0$ cm.
  - We generate different masses of H_0s and A_0s.
    - H_0 = 130 GeV and 170 GeV
    - A_0 = 20 GeV, 40 GeV, and 65 GeV
  - The A_0s are constrained to decay into b, bbar quark pairs.
  - The MC also simulates an underlying event.



Model Diagrams

Diagram not to Scale



Here the Higgs decays at the primary vertex (the X). S represents the heavy pseudoscalar with a long lifetime, which decays into bbbar pairs.
The pink cones represent the hadronization of the B hadrons into jets.
The red represents reconstructed secondary vertices and their corresponding momenta.

MC Studies

- Compared this signal MC to a background MC, QCD bbbar (also Pythia).
- A tactic of this search is to use SecVtx because it is already used for Top physics.
  - B-tagging is vertexing tracks displaced from the primary vertex to determine if there is a secondary vertex.
  - SecVtx the canonical secondary vertex finder at CDF.
- Unfortunately because SecVtx is designed for Top physics it has certain limitations
  - There is a d_0 cut on tracks considered for vertexing ($d_0 < 0.15$ cm).
    - d_0 is the 2-dimensional distance of closest approach of the track to the primary vertex, i.e. the impact parameter.
  - Our MC study showed that few tracks from a $c\tau = 1$ cm displaced decay vertex will pass this cut.
- As a result we loosened this d_0 cut in the MC for studies.
  - A new b-tagger was written, TStnSVF, which allows me to change this max d_0 cut on tracks easily, without reprocessing all the data.

ZBB Trigger

- The ZBB trigger was simulated when analyzing the MC.
  - This is the trigger in which we will investigate as our “signal region.”
- Details of the trigger are in a backup slide.
  - At L2, the trigger requires two SVT tracks with d_0 > 160 microns and d_0 < 1000 microns. This is the displaced track trigger.
  - Dynamically Prescaled Trigger.
    - Through p0-19, this trigger has recorded about 2.2 fb^{-1} of data.
- Nothing in this trigger precludes our signal.

Event Selection

- For these MC studies we use the HEPG block to look at jets we know come from a b-quark whose mother is one of the two A_0s.
- Event must pass ZBB trigger, for both signal and background MC events.
- We investigate events with 0.4 cone central tagged jets.
  - A jet must have match a b-quark from an A_0 with a ΔR cone of 0.4.
  - $|\eta|<1.0$
  - positive TStnSVF b-tag
- To understand our signal, we do not require any E_T or M_{jj} cuts.
- Events that have two (or more) tags are separated into two categories for signal.
  - Two b-tags originating from a single A_0.
  - Two b-tags, each originating from a unique A_0. This is called "one tag each."
- For the background MC we just take events that have two b-tags.

TStnSVF

- TStnSVF is a (T)Stntuple Secondary Vertex Finder.
- The algorithm is the same as SecVtx, but the input data is from the Stntuple instead of Production data.
- The code allows the user to change the parameters of the module in the same way as the tcl talk-tos for SecVtx.
  - Adjustments can be made to the jet, track, and vertex cuts used by the algorithm.
- In order to “validate” this b-tagger I performed a number of studies:
  - Mistag matrix analysis.
  - Calculated b-tagging SF and efficiencies for data and MC.
  - Calculated the mistag asymmetry variables $\alpha*\beta$.
- These were performed with tight-level cuts and data from p0-8.
- No systematic uncertainties are included in these studies
  - Because we want to change the d_0 cut.
  - The thinking is to see what the results are first, change the d_0 cut, then consider the systematics.

Differences Between Algorithms

- Stntuple does not contain 100% of the information that Production has, and thus my algorithm and SecVtx will have differences.
  - Si databases are not available (or at least not readily available) and thus some track quality cuts cannot be reproduced.
  - However, these wind up being second-order effects.
  - The main source of differences are what I call “resolution” effects where a variable lies on either side of a parameter cut.
  - Example: For a d_0 significance cut of 3.5;
    - one data source has a value of 3.49,
    - the other has a value of 3.51.
- In addition, my algorithm does not recalculate the primary vertex location.
  - Instead it mimics SecVtx by asking the ZVertex algorithm for the best class 12 vertex, and finding the closest PrimeVtx Finder vertex from this “seed” vertex.
  - Functionally, this has the result of asking for the best vertex class 12 in the PrimeVtx Finder block since the two almost always find the same vertex.

Validation Results

- Below is a table of the final results of the three validation analyses.
  - More details are located on the backup slides.
- Using the mistag matrix analysis used by the BTSF group, the positive and negative tag ratios between the two taggers is nearly 1.0
  - Differences can be attributed to the differences between the b-taggers explained previously.
- The Scale Factors are nearly identical.
  - Calculated using the muon method (CDF Note 8640).
- The mistag asymmetry variables ($\alpha\beta$) are nearly identical as well.

Pos. Tag Ratio	0.954 ± 0.0004
Neg. Tag Ratio	0.962 ± 0.0008

B-tagger	Scale Factor
TStnSVF-tight	$0.934 \pm 0.0161 \pm 0.0189$
SecVtx-tight	$0.942 \pm 0.0156 \pm 0.0192$

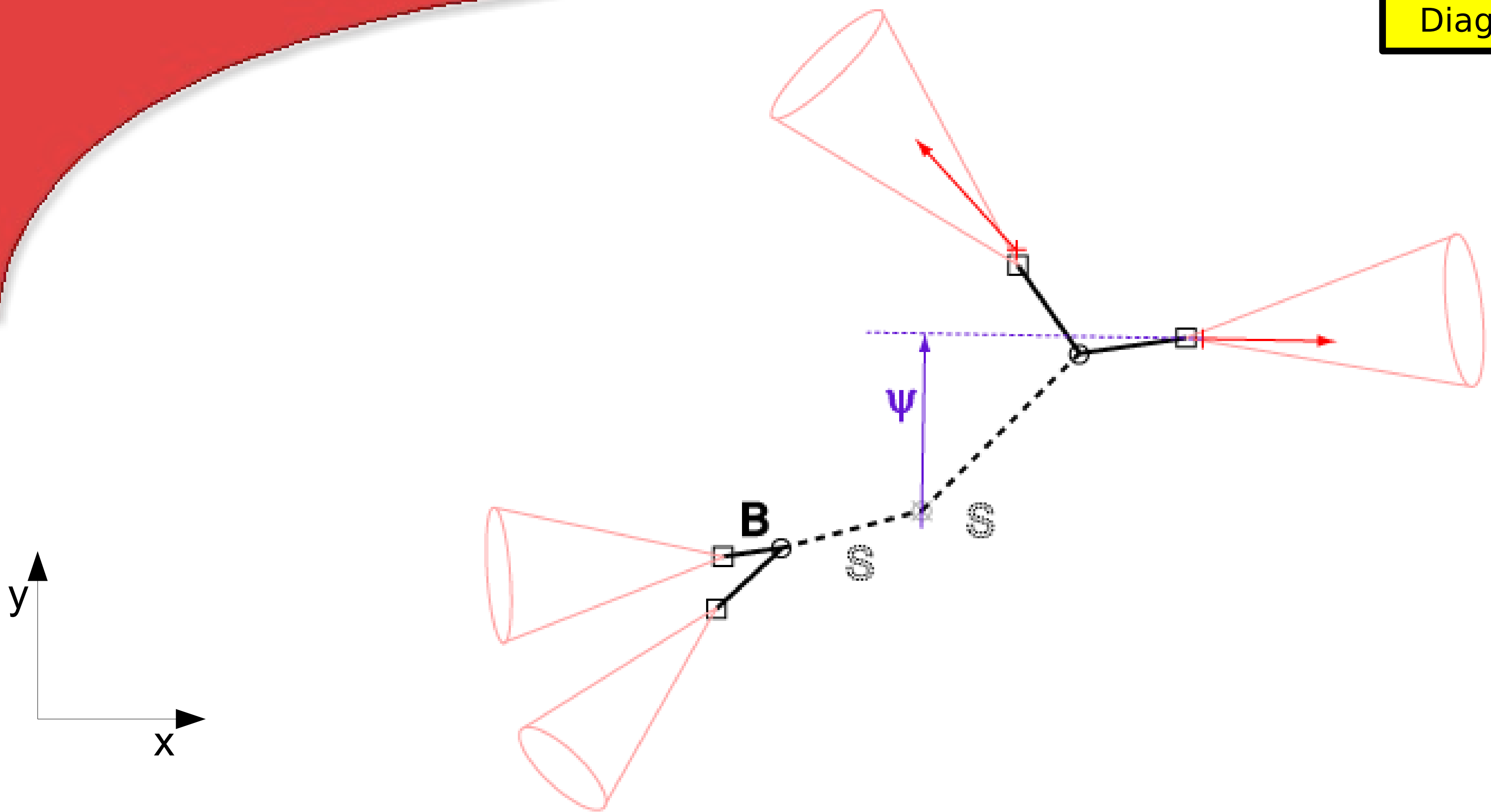
TStnSVF-tight	10-22 GeV	22-40 GeV	40-60 GeV	60-1000 GeV
$\alpha\beta$	1.399 ± 0.1149	1.416 ± 0.1242	1.460 ± 0.1120	1.559 ± 0.0998
SecVtx-tight				
$\alpha\beta$	1.360 ± 0.1301	1.339 ± 0.1567	1.497 ± 0.1157	1.553 ± 0.0782

TStnSVF Summary

- To summarize, TStnSVF is a b-tagging algorithm that runs on Stntuple data.
- It is a clone of SecVtx and performs with near identical results.
- For more details, including many histograms showing comparison between the two b-taggers, see the URL:
  - http://www-cdf.fnal.gov/htbin/twiki/bin/view/ZtoBBbar/TStnSVF
- Or see the CDF Note 9689.

ψ/ζ Diagrams

Diagram not to Scale

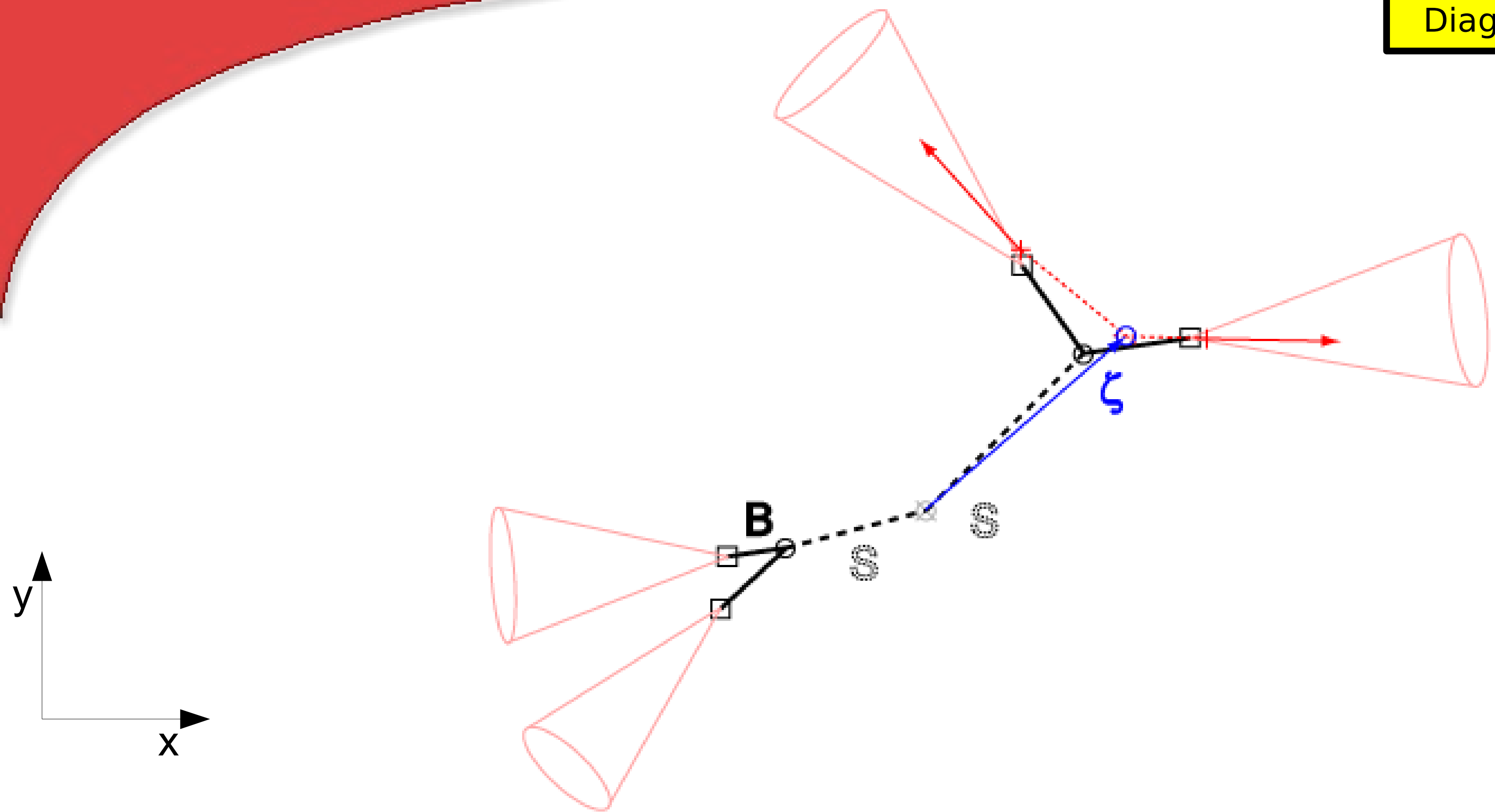


ψ is the impact parameter of a jet with a secondary vertex.

This is in two-dimensional space.

ψ/ζ Diagrams

Diagram not to Scale

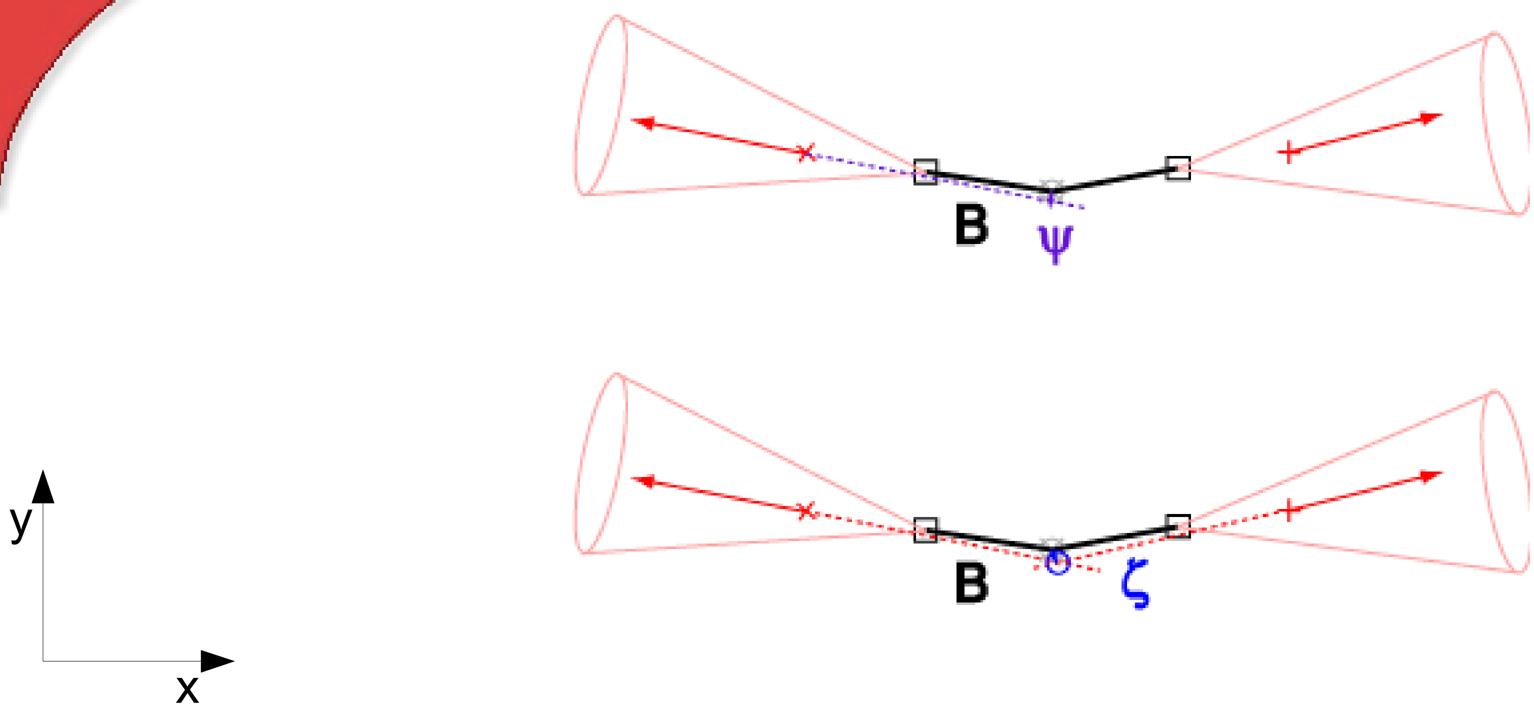


ζ is the reconstructed decay distance of the heavy pseudoscalar S (A_0). It requires two tagged jets.

This is in two-dimensional space.

Background Diagrams

Diagram not to Scale

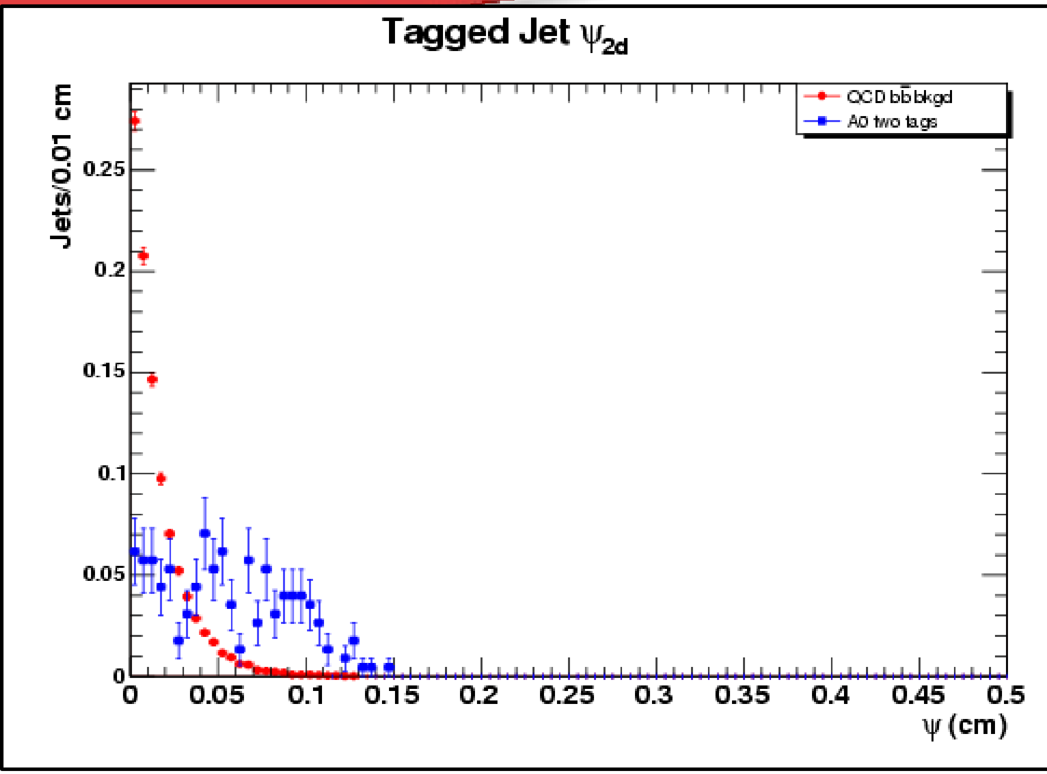


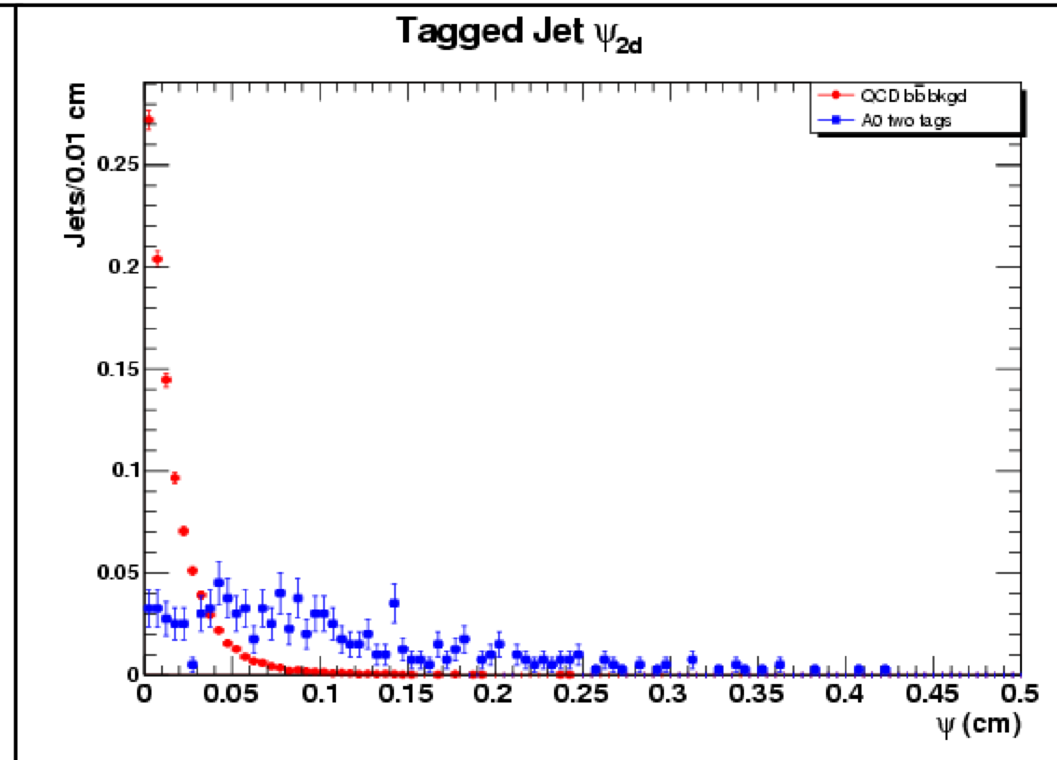
Here is a typical QCD di-jet event with two b quarks (b & bbar) decaying into two B hadrons. Each has a reconstructed secondary vertex represented by a red cross. Both ψ/ζ are very small for these background events.

Discriminants

- New Variables were developed: Psi(ψ) and Zeta(ζ).
- ψ is the impact parameter of the jet.
  - Take the secondary vertex of a jet, it has a position and a direction (momentum), which can be traced back to the primary vertex to give a distance of closest approach (DCA) in 2-dim space.
- ζ is the distance from the primary vertex to the intersection of multiple jet directions in 2-dim space.
  - This is the reconstructed decay vertex of the A_0 (candidate A_0).
  - It can be positive or negative (like a b-tag).
- There are a few more discriminants of use, but they are not very powerful.
  - Delta R between the jets.
  - Distance between the secondary vertices (ΔS).
  - Average L_{2d} of the secondary vertices.
    - L_{2d} is the two-dimensional distance of the secondary vertex to the primary vertex, projected onto the momentum vector of the jet.
  - See backup slides for details
- As reminder, both signal MC and QCD bb background MC events must pass the ZBB trigger.
- The Signal MC masses in these histograms are H_0 = 130 GeV and A_0 = 40 GeV.

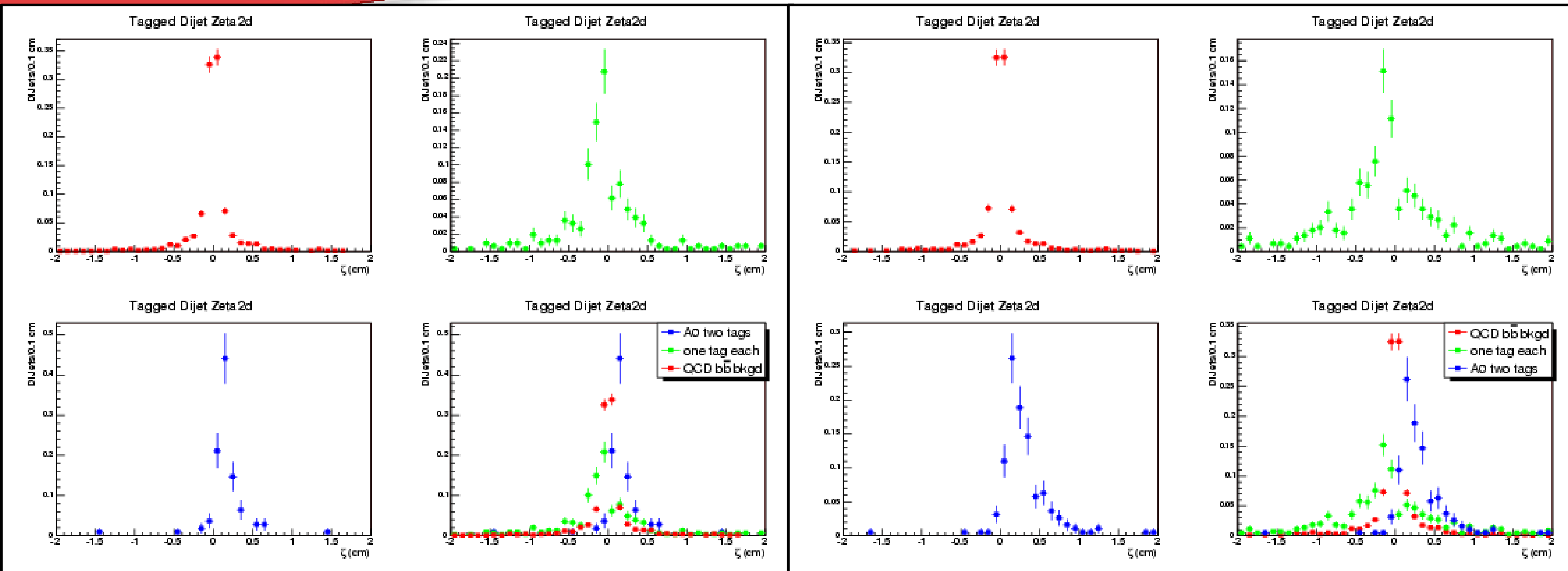
ψ Histograms





- ψ is the Jet impact parameter
- Left: $d_0 < 0.15$ cm ; Right $d_0 < 0.45$ cm
  - Blue: Signal MC, b-quark jets from A_0s.
  - Red: b, bbar dijet MC for comparison
  - Histograms have been normalized to one.
- This is to give a flavor of what we are looking at, without showing dozens of histograms.
- When the d_0 cut is relaxed, we gain signal events, especially along the tail.

ζ Histograms



- ζ is the reconstructed decay vertex of the A_0.
- Left: d_0 < 0.15 cm ; Right d_0 < 0.45 cm
  - Blue: Signal MC, b-quark jets from A_0s.
  - Green: The case where one tagged b-quark jet is from one A_0 while the other tagged b-quark jet is from the other A_0.
  - Red: b, bbar dijet MC for comparison
- Backgrounds are distributed around zero, while signal is nearly all positive.

Backgrounds

- In the previous histograms I have shown QCD dijet b,bbar MC as background.
  - This was done to provide a visual comparison.
  - The QCD background is much larger than what is shown.
- In addition, Pythia MC is not a very good substitute for the background.
  - Detector effects that create more fake b-tagged jets than MC can model.
- We plan to use data-driven backgrounds for this analysis.

Ongoing Work

- Three ongoing tasks are being performed for this analysis:
  - Signal MC generation and reweighting.
  - Deciding on the max d_0 cut for the b-tagger.
  - Building p.d.f.s of jets to determine the background in data.
- Signal MC generation:
  - I generated small samples to understand the signal and to look for discriminants.
    - These were done with different mass points and a A_0 lifetime of 1.0 cm.
    - About 100,000 events for each mass sample. But after trigger efficiency and b-tagging efficiency, this number is reduced to around 2,000 events.
  - We are currently generating samples of around 1M events at the same mass points, and with lifetime of 1.0 cm.
    - We plan on reweighting the MC to smaller lifetimes in order to study larger regions of parameter space.
  - To verify that this is at all possible I generated another small sample with an A_0 lifetime of 0.05 cm.
  - To this I compared a sample with A_0 lifetime of 1.0 cm, at the same mass point, where the events were reweighted to 0.05 cm.

Signal MC Reweighting

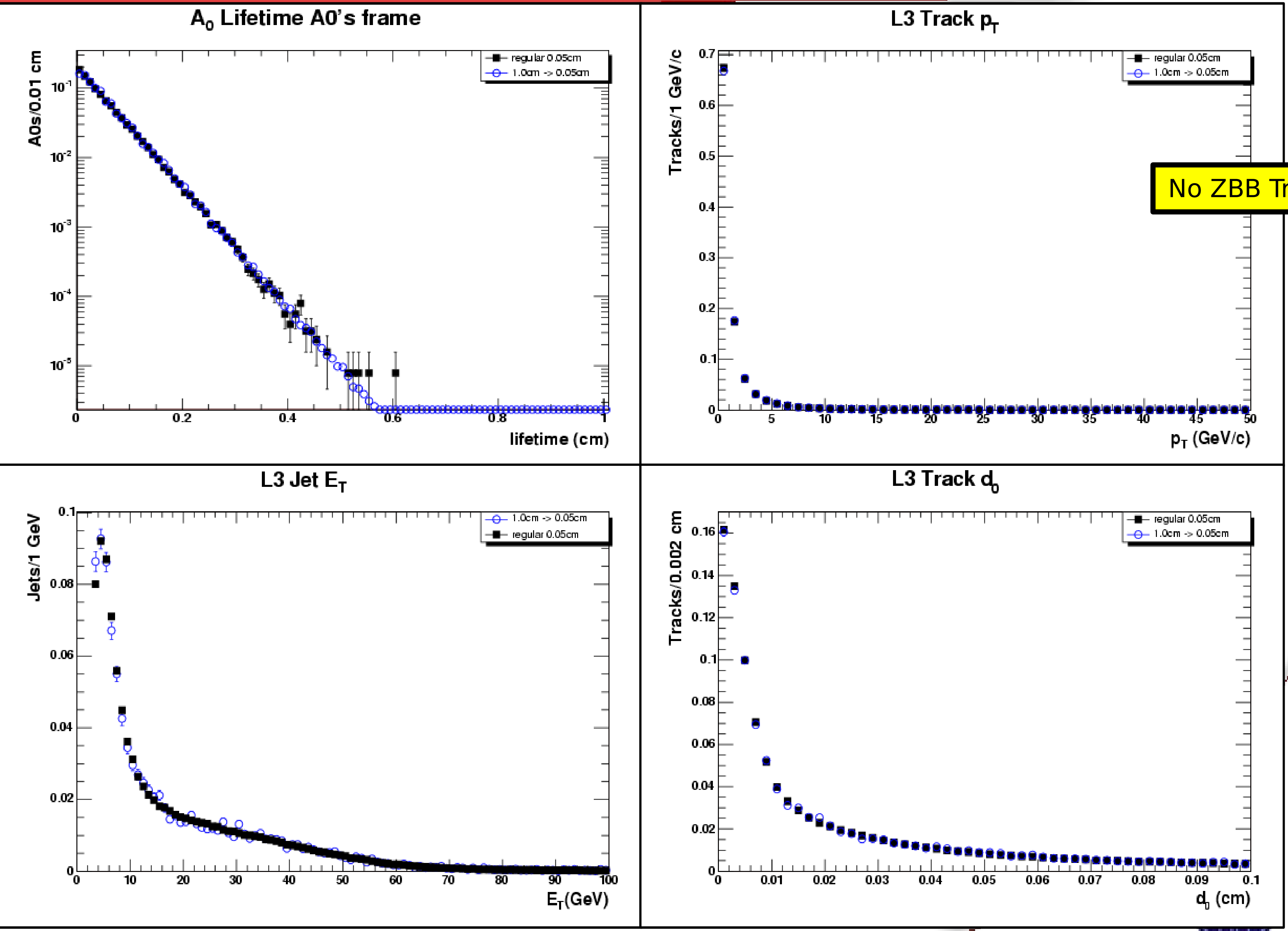
H_0, A_0 Mass (GeV)	A_0 Lifetime (cm)	Number of Events	Triggered Events
170, 65	1.0 reweighted to 0.05	166647	2714
170, 65	0.05	70590	2660

- Both unweighted and reweighted samples were required to pass the ZBB trigger.
- Each A_0 was weighted according to the given formula.
  - Where t is the proper decay time.

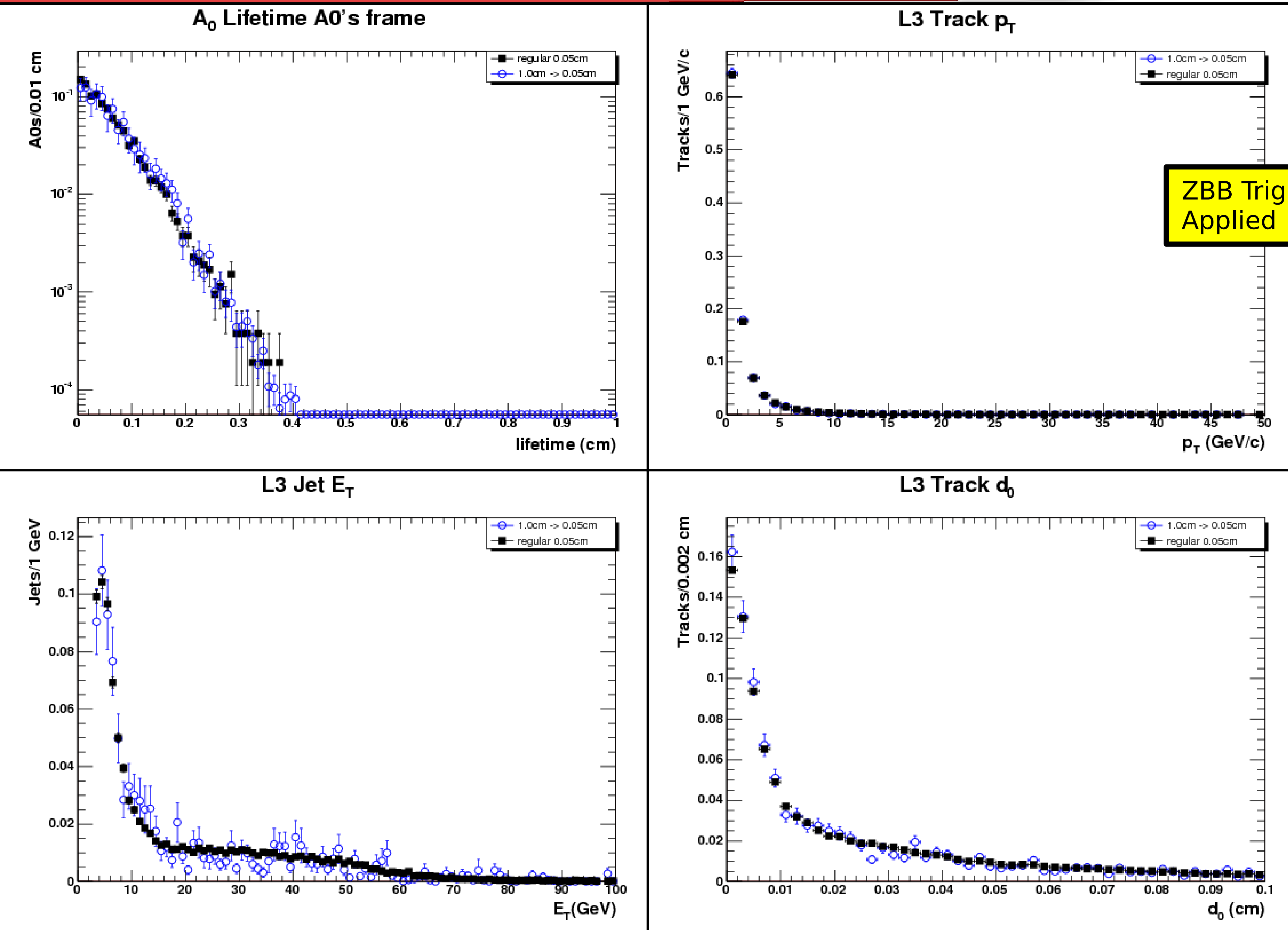
$$weight = \frac{\frac{1}{0.05}e^{-ct/0.05}}{\frac{1}{1.0}e^{-ct/1.0}}$$

- Since there are two A_0s per event, the two weights were multiplied together to give an overall event weight.
- The lifetime of the A_0 taken from the HEPG bank.
  - We divide by Energy/Mass (γ) to use the proper lifetime.
- Compare distributions of basic event variables (tracks, jets, etc.) for both the weighted and unweighted samples.
  - The first slide shows variables before the trigger was applied.
  - The second slide shows variables after the trigger was applied.
  - Histograms have been normalized to 1.0.

Signal MC Reweighting



Signal MC Reweighting

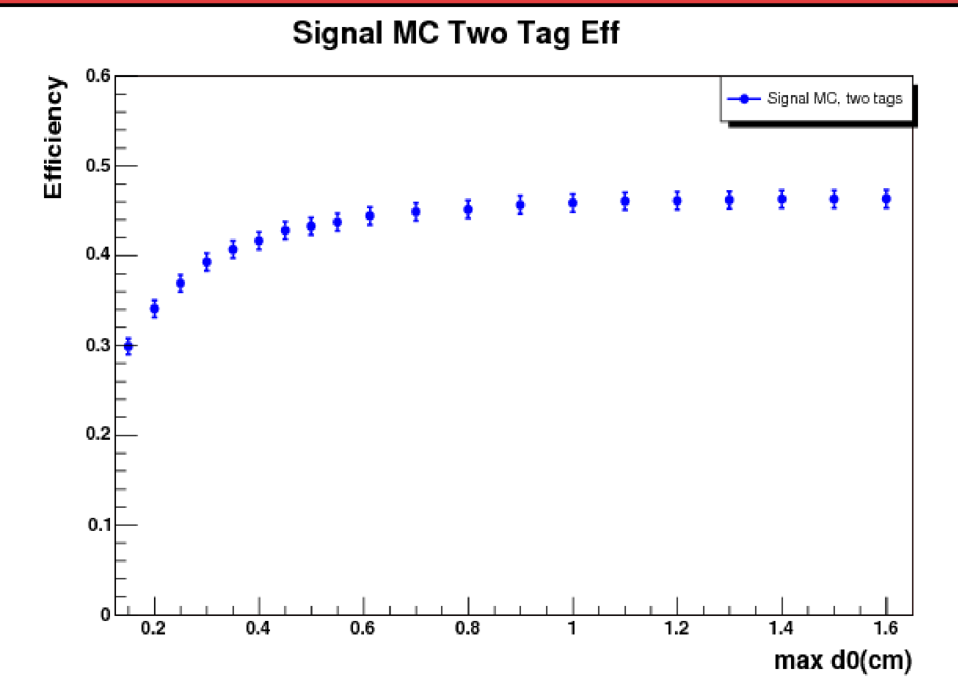


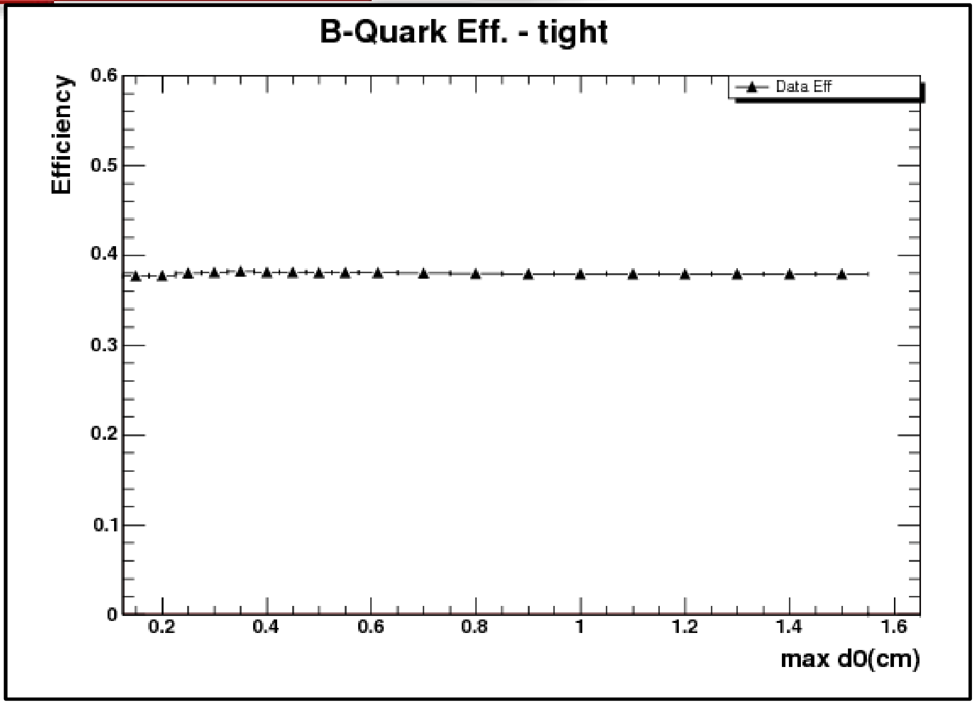
ZBB Trigger Applied

Max d_0 Selection

- To decide on what maximum track d_0 we want TStnSVF to use, we will look at a couple of variables.
- For the signal (MC) we can look at the efficiency of finding two tagged jets per event where each jet is known to come from an A_0.
  - Machinery is in place.
  - See histogram on next slide for an example.
- For data background we can look at the positive and negative tag rates for each max d_0 cut.
  - B-quark efficiency vs. max d_0 cut.
    - This was done with the muon BTSF method.
    - See next slide.
  - Fake rate (aka mistag rate) vs. max d_0 cut.
    - Specifically the fake rate in light jets that are mis-tagged as heavy flavor.
    - The fake rates are currently being processed and calculated.

Max d_0 Selection





- Left – Efficiency for finding two tag events in my signal MC samples, for a single mass point (H_0=170 GeV, A_0=65 GeV) and lifetime (1.0 cm).
  - Efficiency increases with larger max d_0 because the B hadrons are generated at a displaced (secondary) vertex away from the primary.
- Right – Efficiency for finding b-quark jets in real data.
  - Muon B-Tagging Scale Factor (BTSF) method.
    - bmclxx dataset, p0-19, 8 GeV muon calibration trigger
    - Pythia QCD MC datasets (btopla, btopqb, btopqr)
  - Requires lepton-jet & away-jet combination, see CDF Note 8640 for details.
  - The efficiency is flat because the B hadrons originate from the primary vertex.

Analysis Strategy

- The analysis strategy is to remove as much of the background as possible.
  - The signal cross section (SM Higgs) is < 1 fb while the backgrounds are many orders of magnitude larger.
  - We need to find a background-free region. Thus we are searching for any events above zero.
- We need real data based background.
  - Build p.d.f.s for “background” jets for a couple of variables
    - Mundane b background: QCD bb, ttbar, ZZ etc.
    - Mundane c background: QCD cc, ZZ
    - Light flavor background: QCD qq/gg
    - (Others such as tau hadronic)
  - Use data triggers when possible to build these p.d.f.s.
    - Muon/Electron calibration data, which is rich is heavy flavor jets
    - Pythia QCD cc MC
    - Single Tower 5, 10 jet data, for light-quark and gluon jets
  - These p.d.f. are per jet (not per event).
  - These per jet p.d.f.s can be applied to multijet QCD production, either data or MC, to estimate the final background and decide on the ψ and ζ cuts.
- Then we use the ZBB trigger data to search for the signal.
  - Make a series of signal region cuts using variables like Delta R, etc.
  - Make the ψ and ζ cuts.
  - Plot the resulting dijet mass distributions.

Signal Event Selection

- The signal region event selection has not been finalized. This is still ongoing work.
- We will be looking for events with two central tagged jets, with a relatively low E_T requirement.
  - Event jet multiplicity: $N_{jet} \geq 3$
  - E_T > 20 GeV, corrected at Level-5
  - $|\eta|<1.0$
  - positive TStnSVF b-tags only
- For the dijet system, require that it be in a region we know there to be signal.
  - $\Delta R < 2.5$
  - Again not all of these have been finalized.
- Finally, make cuts on ψ and ζ which are part of the background estimation of this analysis.

Conclusion

- Displaced vertices
  - We are searching outside the standard model using displaced vertices.
  - The Hidden Valley model provides a number of phenomenologies to search for at colliders, and predicts displaced vertices as a signature of said phenomenon.
  - Higgs production is one production model where displaced vertices may help.
- Signal MC studies show that the track d_0 cut in SecVtx removes many of our signal events.
- TStnSVF - We have a new b-tagger, that allows us to change this d_0 cut
  - It behaves nearly identically to SecVtx.
- Discriminants
  - I've shown histograms of the impact parameter and the reconstructed decay vertex of the A_0, and how they differ between signal and background (MC).
- The Analysis
  - Signal Monte Carlo Generation – 1st pass done
    - We plan to reweight this MC to increase our sensitivity to different values of the model parameters.
  - Max d_0 Selection – ongoing
    - Fake rate calculations are being completed.
  - Determining background from data – ongoing
    - P.d.f.s are also being constructed.

Backup Slides

- ZBB Trigger Details
- SecVtx outline
- TStnSVF validation details
- Additional diagrams
- Additional discriminants

ZBB Trigger

- Details of the trigger in the trigger table:
  - L1 :
    - one central tower with $E_T > 5$ GeV
    - two XFT tracks, $p_T^1 > 5.48$ GeV, $p_T^2 > 2.46$ GeV
  - L2 :
    - veto events w/ clusters with $E_T > 5$ GeV, $|\eta| > 1.1$
    - requires two clusters $E_T > 5$ GeV, $|\eta|<1.1$ which have $9 < \Delta\text{Wedge} < 12$
    - two SVT tracks with $p_T > 2$ GeV, $d_0 > 160$ microns, $d_0 < 1000$ microns, $\chi^2 < 12$,
      - $150 < \Delta\phi < 180$ “Opposite Side”
      - $0 < \Delta\phi < 30$ “Same Side”
      - This triggers on displaced tracks in the event.
  - L3:
    - two R=0.7 jets with $E_T > 10$ GeV, $|\eta| < 1.1$
    - two SVT tracks with $p_T > 2$ GeV, $d_0 > 160$ microns, $d_0 < 1000$ microns, $|\eta| < 1.2$
    - two tracks with $p_T > 1.5$ GeV, $d_0 > 130$ microns, $d_0 < 1000$ microns, $|\eta| < 1.2$,
      IP significance $Sd_0>3$, $\Delta z < 5$ cm
  - Dynamically Prescaled Trigger
  - This is for the latest trigger “chunk,” #17. Chunks 10-16 are nearly the same, with minor changes in the cut values, but the structure is the same.

SecVtx Overview

- The SecVtx algorithm in a nutshell:
- SecVtx finds a primary vertex in the event.
  - It uses the best ZVertex vertex as the “seed” vertex.
  - It uses the PrimVtx Finder algorithm to find a vertex using said seed vertex, constraining the result to the beamline.
- Next it selects tracks for vertexing.
  - There are numerous track cuts: z_0, d_0, z_0 Significance, d_0 Significance, silicon hits, etc.
  - Tracks are flagged as pass1 or pass2, the latter having more stringent requirements, but is a subset of the former.
- Vertexing is performed using two strategies: pass1 and pass2
  - Seed vertexes are formed using each pair of pass1 tracks.
  - Tracks are added to the vertex based on the d_0 Significance of the additional track and the seed vertex location. At least three tracks in total must be used before a vertex is declared.
  - If no pass1 vertex is found, pass2 tracks are vertexed together.
  - Two tracks minimum are required for pass2 vertexing.
- Regardless the vertex is then pruned of tracks that contribute a chi-squared deemed too high, the quantity depending on whether the algorithm is using the loose, tight, or ultratight cuts.
- The vertex decay length (L2d Significance) is cut on, among other variables.
- vertices are checked not to be from a K_S or Λ, and not

  in the material of the detector.

Mistag Matrix Results

- Tagger Comparison Analysis: A mistag matrix was built using SecVtx from all jet samples (JET_20, 50, 70, & 100), all events.
- The observed rate is from the TStnSVF tagger from the jet samples as well.
- The predicted rate is from the mistag matrix.
  - The ratio is observed/predicted.

Tag Rate	**JET_20**	**JET_50**	**JET_70**	**JET_100**	**All JET**
Observed Positive	0.01574	0.02840	0.03325	0.03985	0.02928
Stat. Error (+/-)	2.5640E-05	4.3989E-05	4.4345E-05	4.0549E-05	1.2577E-05
Predicted Positive	0.01605	0.02981	0.03506	0.04204	0.03070
Stat. Error (+/-)	3.7826E-06	9.1439E-06	9.5346E-06	9.8640E-06	3.9931E-06
Ratio	0.98024	0.95261	0.94839	0.94780	0.95366
Stat. Error (+/-)	1.6139E-03	1.5042E-03	1.2910E-03	9.8973E-04	4.2798E-04
Observed Negative	0.00323	0.00814	0.01059	0.01472	0.00924
Stat. Error (+/-)	1.1691E-05	2.3802E-05	2.5318E-05	2.4961E-05	7.1382E-06
Predicted Negative	0.00315	0.00841	0.01114	0.01542	0.00960
Stat. Error (+/-)	1.1425E-06	3.5406E-06	3.7455E-06	4.5108E-06	1.6595E-06
Ratio	1.02390	0.96895	0.95079	0.95440	0.96223
Stat. Error (+/-)	3.7243E-03	2.8609E-03	2.2955E-03	1.6428E-03	7.6157E-04

- Overall my TStnSVF b-tagger is a little lower in its tag rate than SecVtx.
  - I believe these can be accounted to the differences in the algorithms described earlier.

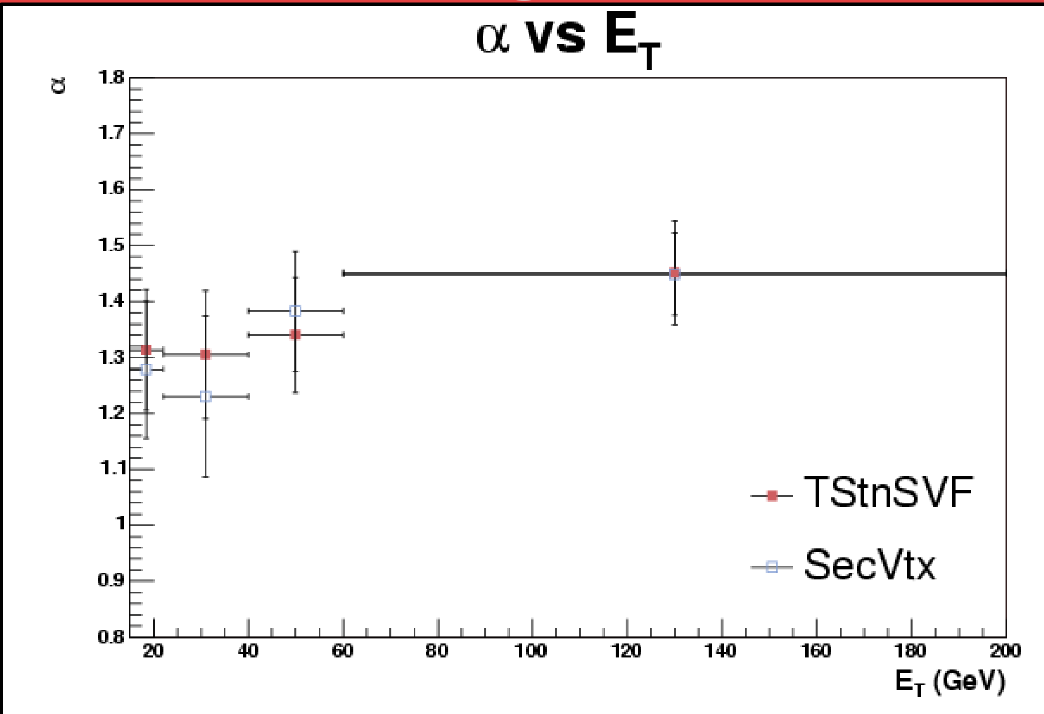
Scale Factor Results

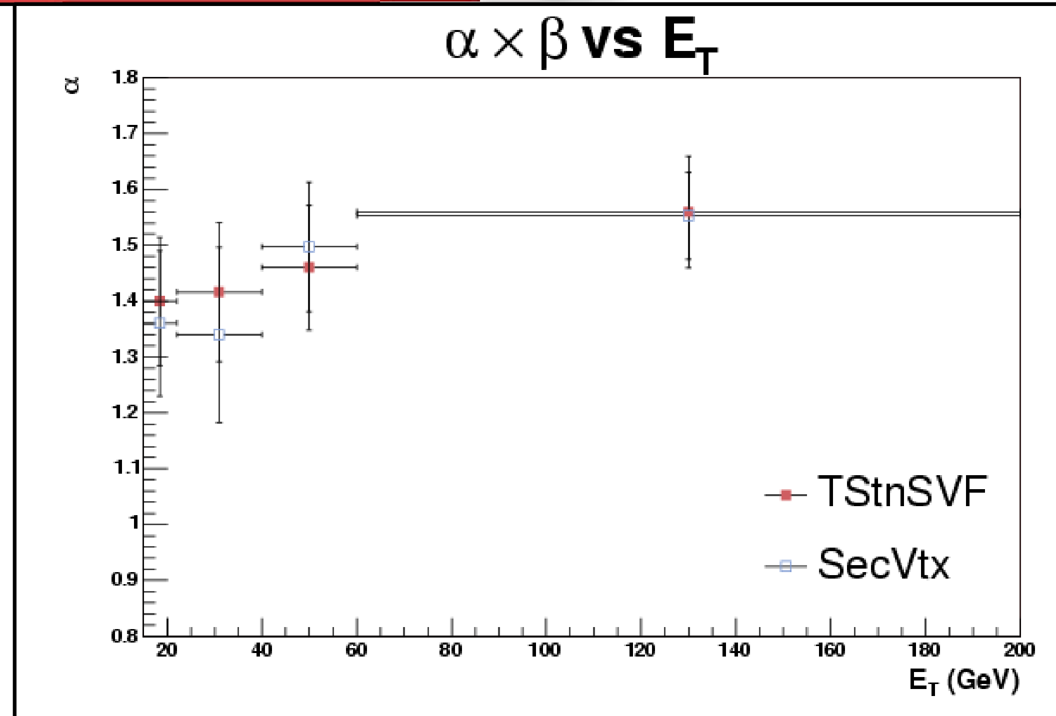
- B-Tagging Scale Factor results for calorimeter based jets, and tight-level parameter cuts.

B-Tagging SF for Cal-jets	TStnSVF – Tight			SecVtx – Tight		
	Value	Stat Err	Sys Err	Value	Stat Err	Sys Err
Total number of muon jets considered	85478			84200		
Number of not positive tagged jets	59528			57596		
Number of positive tagged jets	25950			26604		
Data Efficiency, charm template	0.37218	0.00536		0.39189	0.00545	
Data Efficiency, light flavor template	0.37979	0.00673		0.39884	0.00685	
Data Efficiency, Anti-Match template	0.37063	0.00525		0.39095	0.00534	
Data Efficiency, 0 P1 Tracks template	0.38723	0.00577		0.40844	0.00586	
Avg Data B-Tagging Efficiency	0.37746	0.00578	0.00764	0.39753	0.00588	0.00808
MC B-Tagging Efficiency	0.40412	0.00315		0.42205	0.00315	
B-Tagging Scale Factor	**0.93402**	**0.01606**	**0.01892**	**0.94190**	**0.01561**	**0.01915**

- The TStnSVF and SecVtx results are within statistical errors.
  - The statistical error is the linear combination of the uncertainties of each non-b template. This assumes 100% correlation between the each measurement.
  - The systematic error is the RMS of the individual non-b templates w.r.t the average value calculated.
- This was done with the muon calibration 8 GeV trigger (bmclxx) and the QCD dijet MC samples (btopla, btopqb, btoprb).

Mistag Asymmetry Results





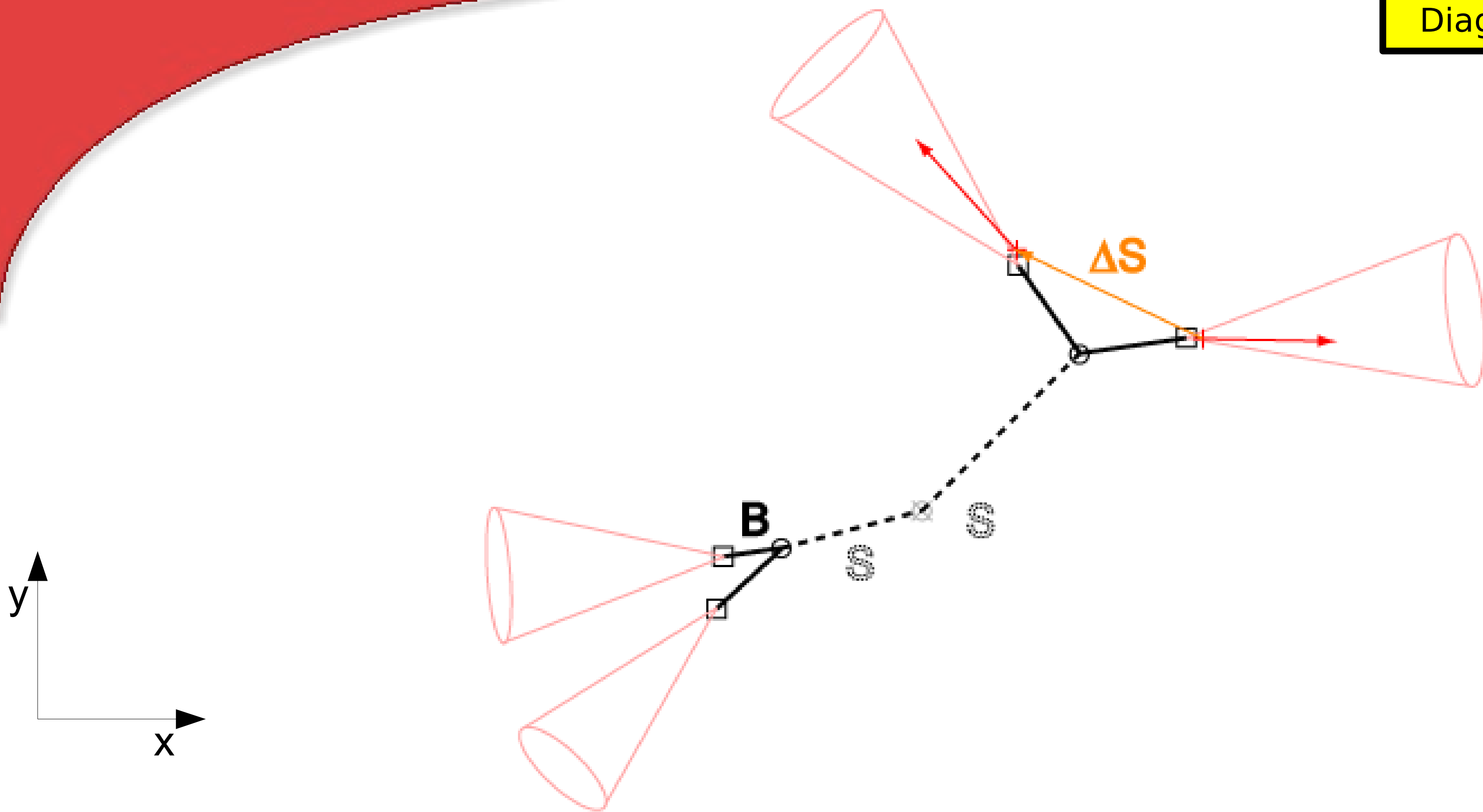
α and $\alpha\beta$ as a function of E_T for both TStnSVF and SecVtx, tight operating points.

TStnSVF-tight	10-22 GeV	22-40 GeV	40-60 GeV	60-1000 GeV
α	1.314 ± 0.108	1.305 ± 0.114	1.340 ± 0.103	1.452 ± 0.093
$\alpha\beta$	1.399 ± 0.115	1.416 ± 0.124	1.460 ± 0.112	1.559 ± 0.100
SecVtx-tight				
α	1.278 ± 0.122	1.230 ± 0.144	1.383 ± 0.107	1.449 ± 0.073
$\alpha\beta$	1.360 ± 0.130	1.339 ± 0.157	1.497 ± 0.116	1.553 ± 0.078

This was done with the four JET triggers and four corresponding QCD dijet MCs (pt 18, 40, 60 and 90): btopqb, btoprb, btopsb, btoptb.

Add. Diagrams

Diagram not to Scale

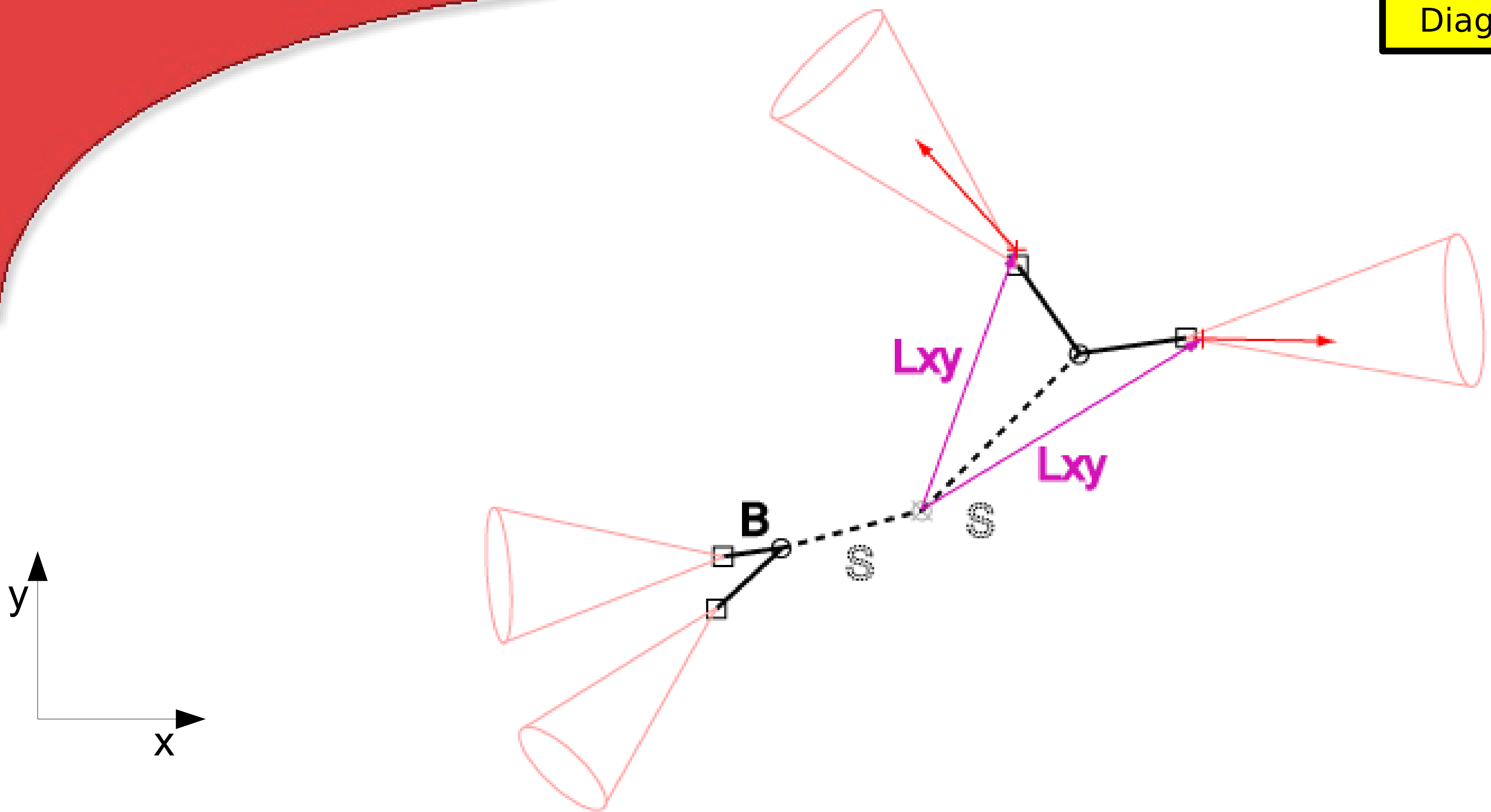


ΔS is the distance between two of the B hadrons decaying from a heavy pseudoscalar S (A_0). It requires two tagged jets.

This is in two-dimensional space.

Add. Diagrams

Diagram not to Scale

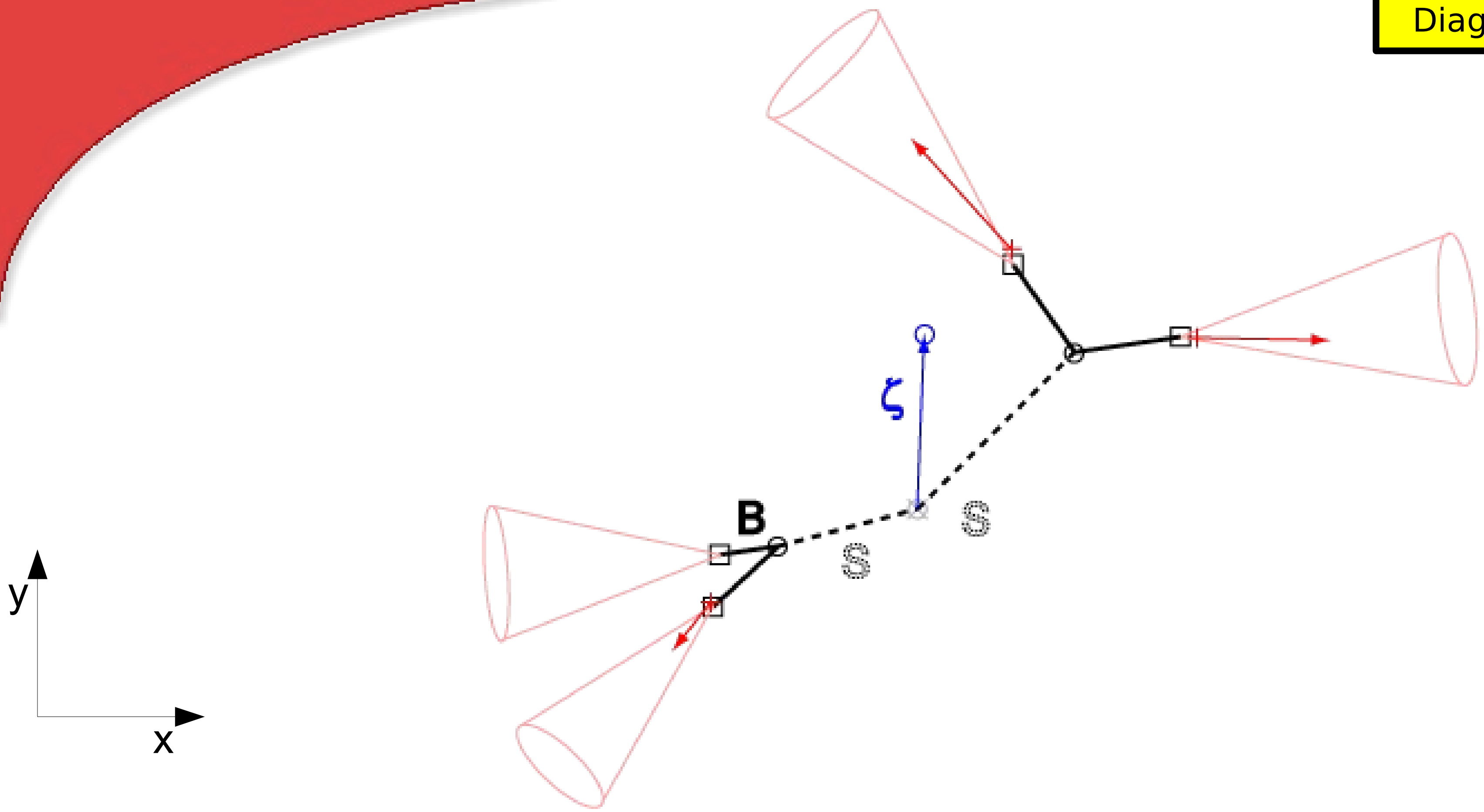


L_{xy} is the two-dimensional distance from the primary vertex to the secondary vertex, shown here for both b-tags. L_{2d} is L_{xy} projected onto the jet momentum vectors (not shown).

This is in two-dimensional space.

Wrong Combination

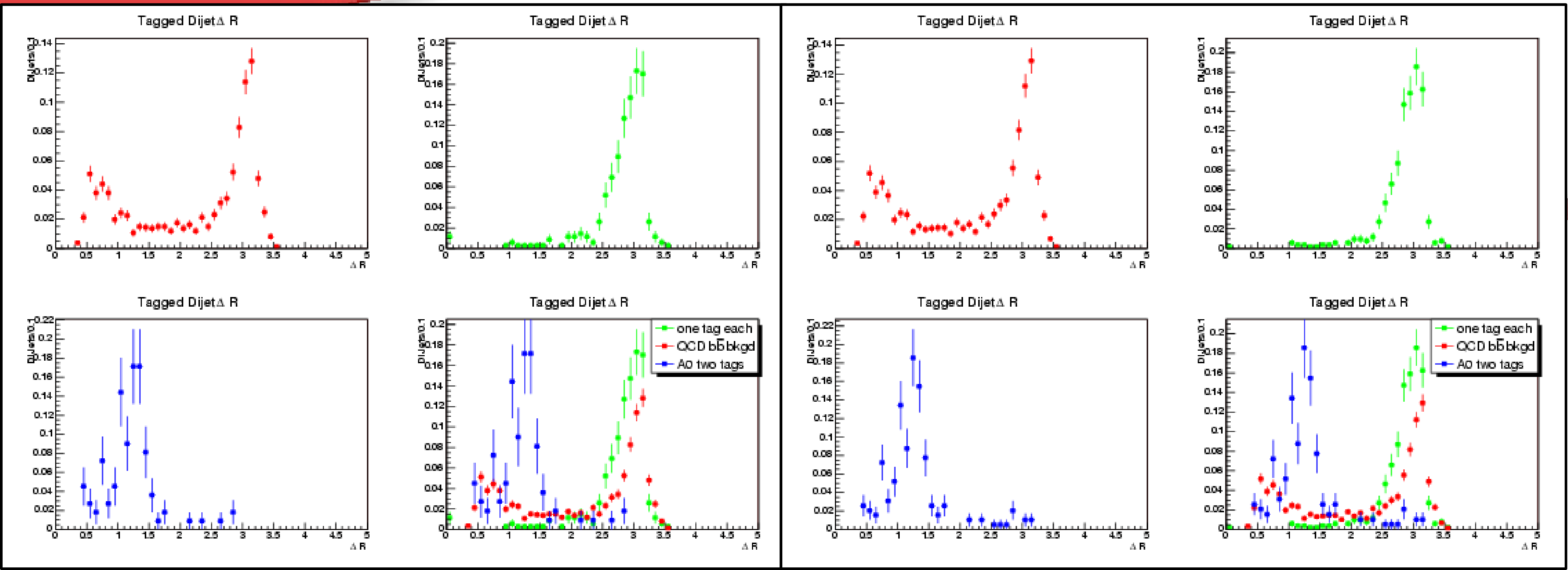
Diagram not to Scale



If two b quarks, each from a different A_0s, are b-tagged, then the wrong combination may be present. In this case, the B at the lower-left and the B from the upper-right has would have ζ shown above.

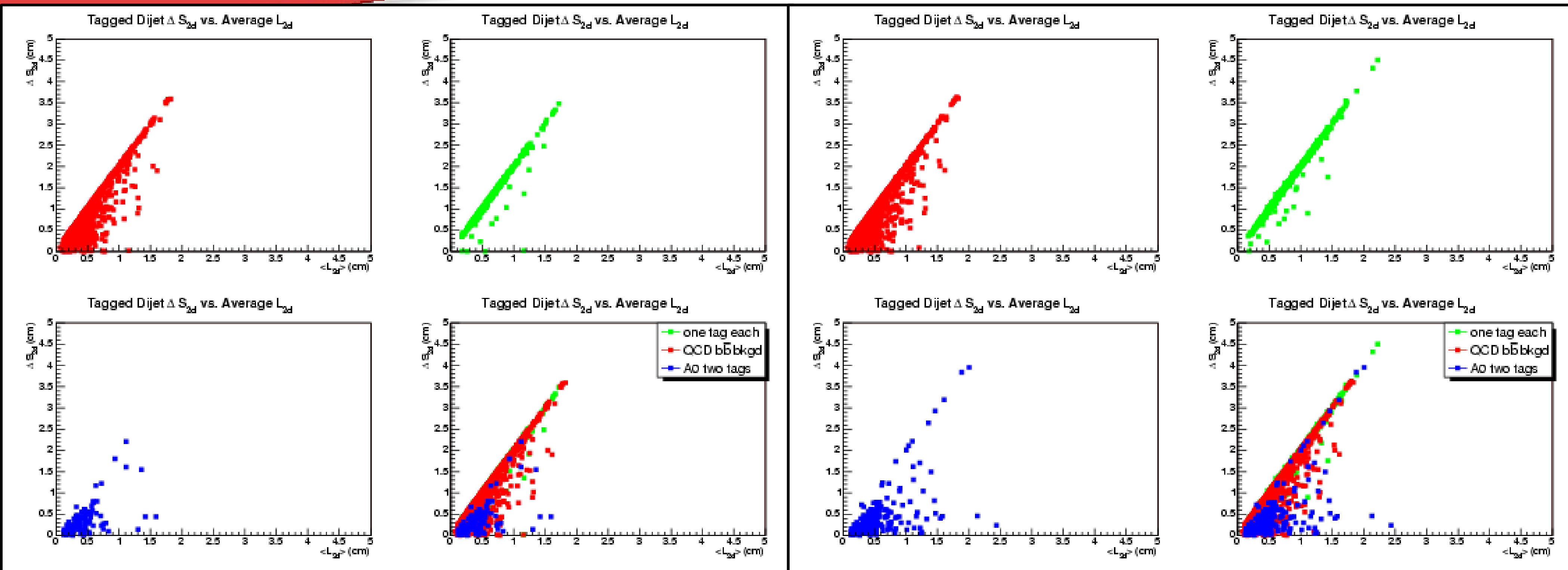
This is in two-dimensional space.

Add. Histograms



- Left: $d_0 < 0.15$ cm ; Right $d_0 < 0.45$ cm
  - Blue: Signal MC, b-quark jets from A_0s.
  - Green: One tag from each A_0.
  - Red: b, bbar dijet MC for comparison
  - Histograms have be normalized to one.
  - ΔR for signal is much smaller than for background.

Add. Histograms



- Left: d_0 < 0.15 cm ; Right d_0 < 0.45 cm
  - Blue: Signal MC, b-quark jets from A_0s.
  - Green: One tag from each A_0.
  - Red: b, bbar dijet MC for comparison
- The x-axis the <L_{2d}> of the two tagged b-jets, the y-axis is the distance between the two secondary veritices.
  - QCD and wrong combo. backgrounds follows a diagonal line.
  - Signal has large <L_{2d}> but small ΔS.